US010721791B1

(12) **United States Patent**
Gamliel et al.

(10) **Patent No.: US 10,721,791 B1**
(45) **Date of Patent: Jul. 21, 2020**

(54) **RECOMMENDING THE REFACTORING OF MICROSERVICES**

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **16/386,524**

(22) Filed: **Apr. 17, 2019**

(51) **Int. Cl.**

G06F 9/44	(2018.01)
H04W 76/36	(2018.01)
G06F 8/72	(2018.01)
H04W 28/02	(2009.01)
G06F 8/41	(2018.01)
G06F 9/50	(2006.01)
H04W 48/06	(2009.01)
H04W 72/12	(2009.01)
H04W 28/16	(2009.01)
H04L 12/26	(2006.01)

(52) **U.S. Cl.**

CPC ***H04W 76/36*** (2018.02); ***G06F 8/433*** (2013.01); ***G06F 8/72*** (2013.01); ***G06F 9/5033*** (2013.01); ***H04W 28/0231*** (2013.01); ***H04W 48/06*** (2013.01); ***H04W 72/1226*** (2013.01); *G06F 9/5066* (2013.01); *H04L 43/0876* (2013.01); *H04W 28/16* (2013.01)

(58) **Field of Classification Search**

CPC G06F 16/24578; G06F 16/9024; G06F 8/443; G06F 9/5044; G06F 11/302; G06F 9/5033; G06F 9/5066; H04L 45/44; H04W 72/10; H04W 76/36; H04W 28/0231; H04W 72/1226; H04W 28/16

See application file for complete search history.

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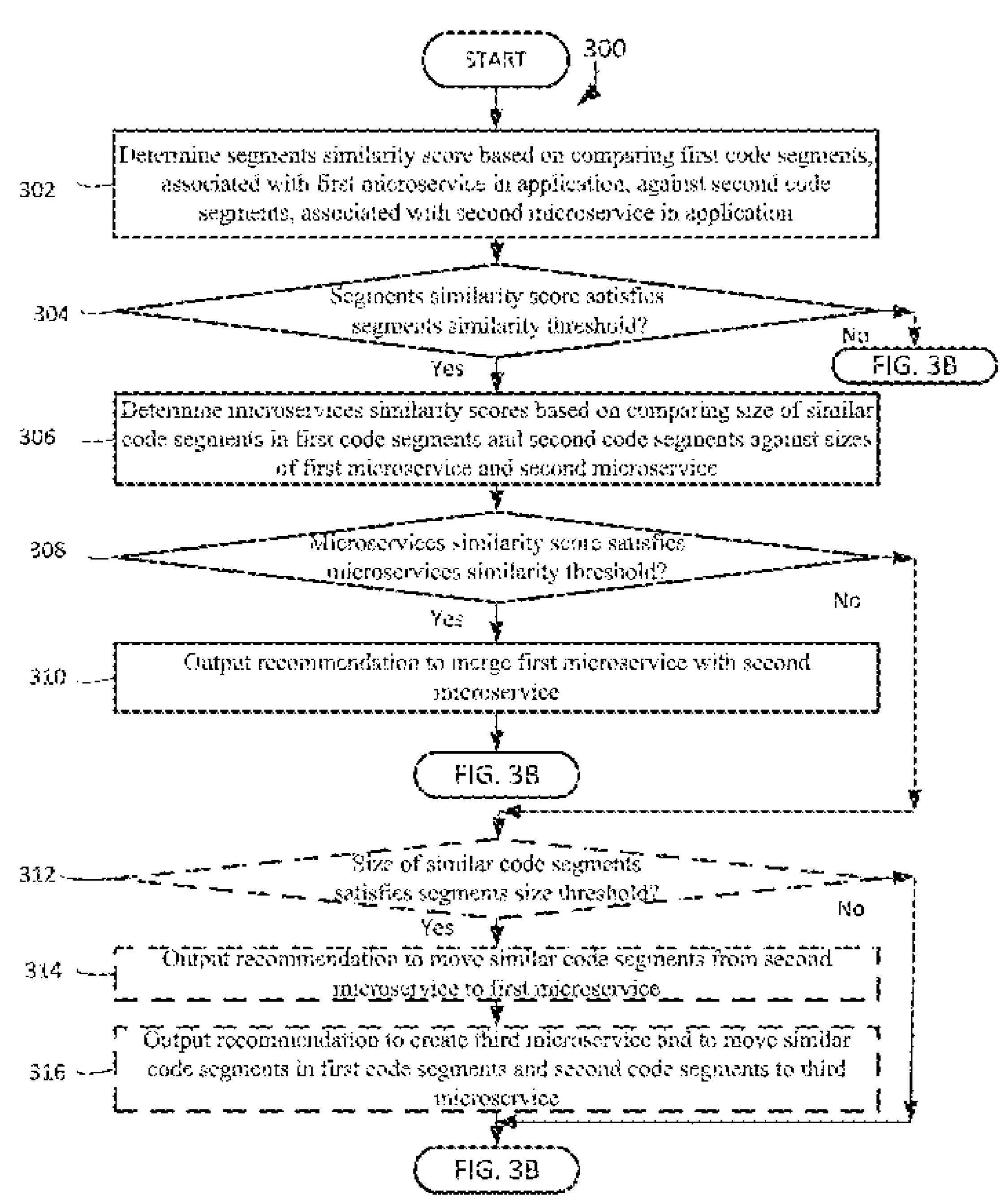
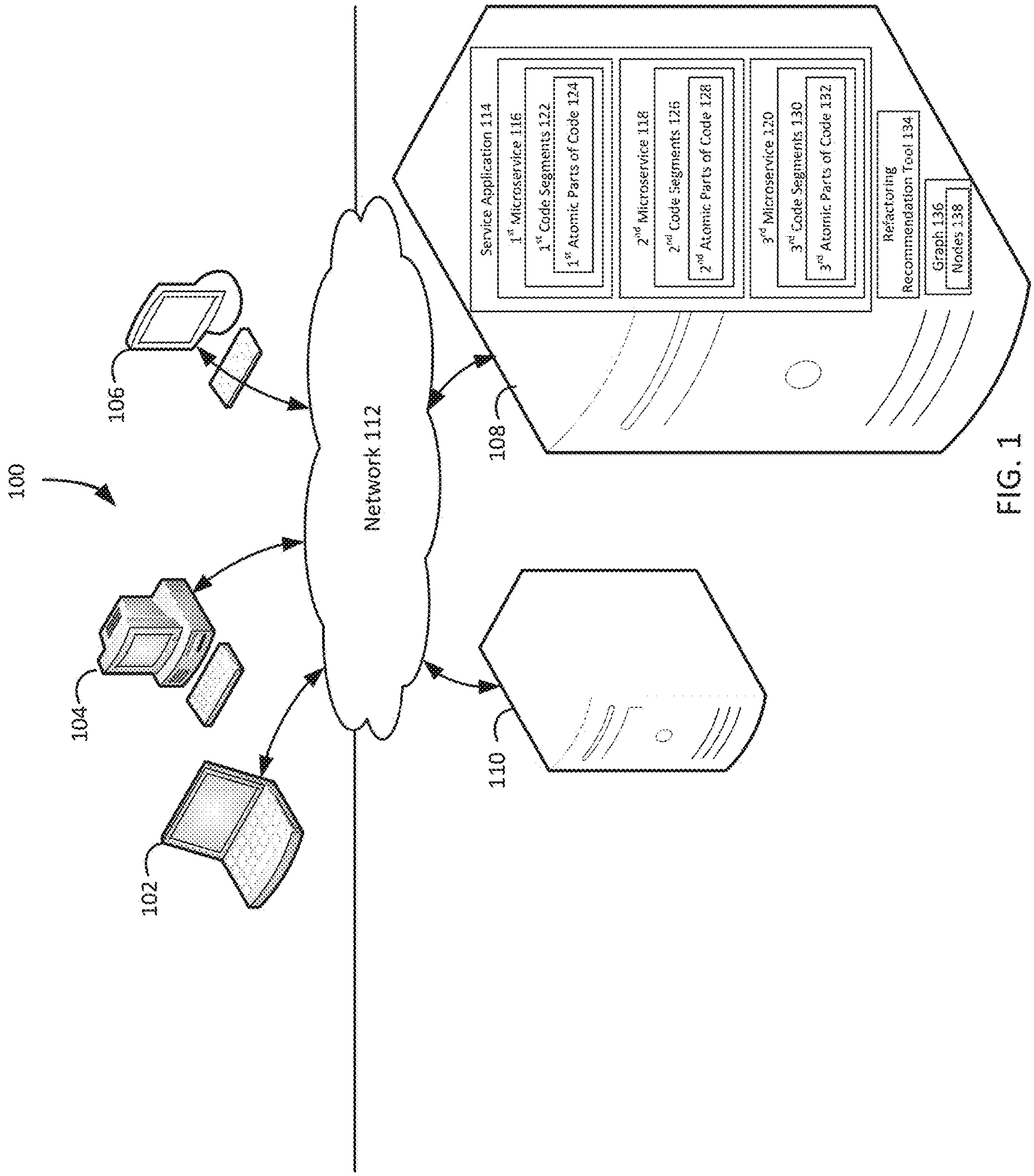
(57) **ABSTRACT**

A system recommends the refactoring of microservices. The system generates a graph of connected nodes including a first node, which represents a first atomic part of code in a microservice in an application, and a second node, which represents a second atomic part of code in the microservice. The system determines a nodes connection score based on any connections between the first node and the second node. If the nodes connection score satisfies a nodes connection threshold, the system determines a relative code size based on comparing a size associated with the first atomic part of code against a size of the microservice. If the relative code size satisfies a code size threshold, the system outputs a recommendation to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice.

20 Claims, 7 Drawing Sheets

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102
104
106
Network 112
108
110
Service Application 114
1st Microservice 116
1st Code Segments 122
1st Atomic Parts of Code 124
2nd Microservice 118
2nd Code Segments 126
2nd Atomic Parts of Code 128
3rd Microservice 120
3rd Code Segments 130
3rd Atomic Parts of Code 132
Refactoring Recommendation Tool 134
Graph 136
Nodes 138

FIG. 1

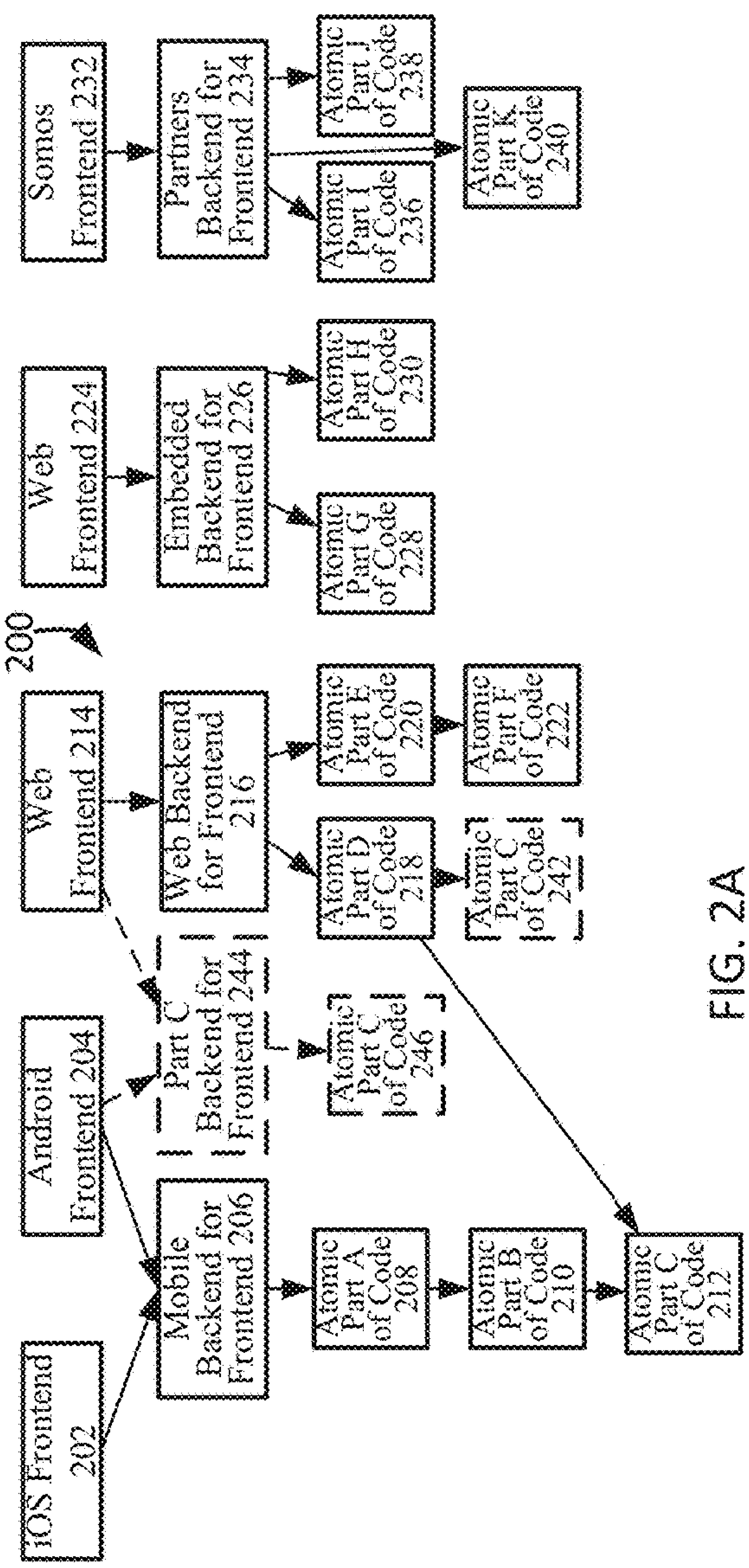

200
iOS Frontend 202
Android Frontend 204
Mobile Backend for Frontend 206
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Part C Backend for Frontend 244
Atomic Part C of Code 246
Web Frontend 214
Web Backend for Frontend 216
Atomic Part D of Code 218
Atomic Part C of Code 242
Atomic Part E of Code 220
Atomic Part F of Code 222
Web Frontend 224
Embedded Backend for Frontend 226
Atomic Part G of Code 228
Atomic Part H of Code 230
Somos Frontend 232
Partners Backend for Frontend 234
Atomic Part I of Code 236
Atomic Part J of Code 238
Atomic Part K of Code 240

FIG. 2A

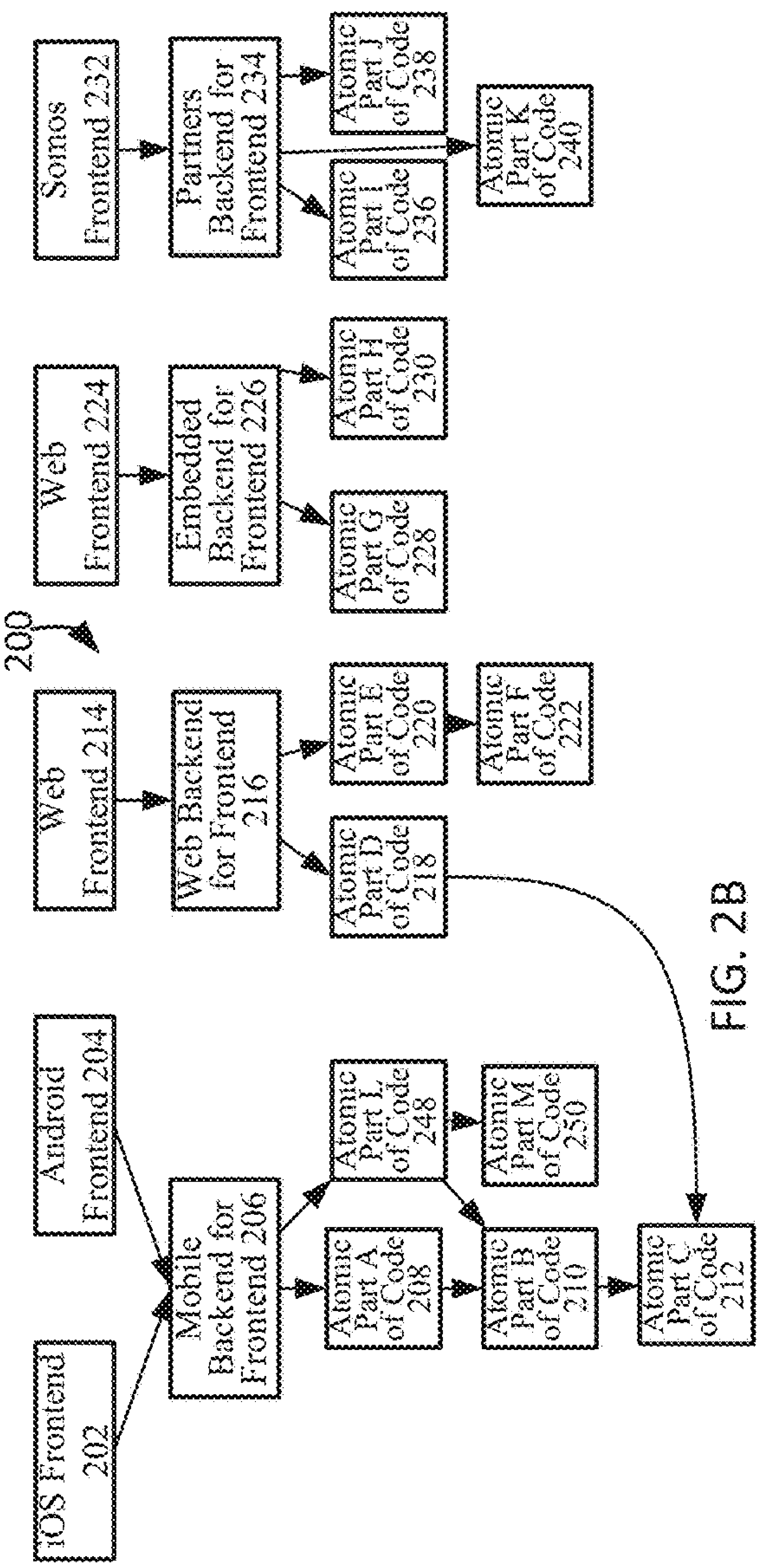

200
iOS Frontend 202
Android Frontend 204
Mobile Backend for Frontend 206
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Atomic Part L of Code 248
Atomic Part M of Code 250
Web Frontend 214
Web Backend for Frontend 216
Atomic Part D of Code 218
Atomic Part E of Code 220
Atomic Part F of Code 222
Web Frontend 224
Embedded Backend for Frontend 226
Atomic Part G of Code 228
Atomic Part H of Code 230
Somos Frontend 232
Partners Backend for Frontend 234
Atomic Part I of Code 236
Atomic Part J of Code 238
Atomic Part K of Code 240

FIG. 2B

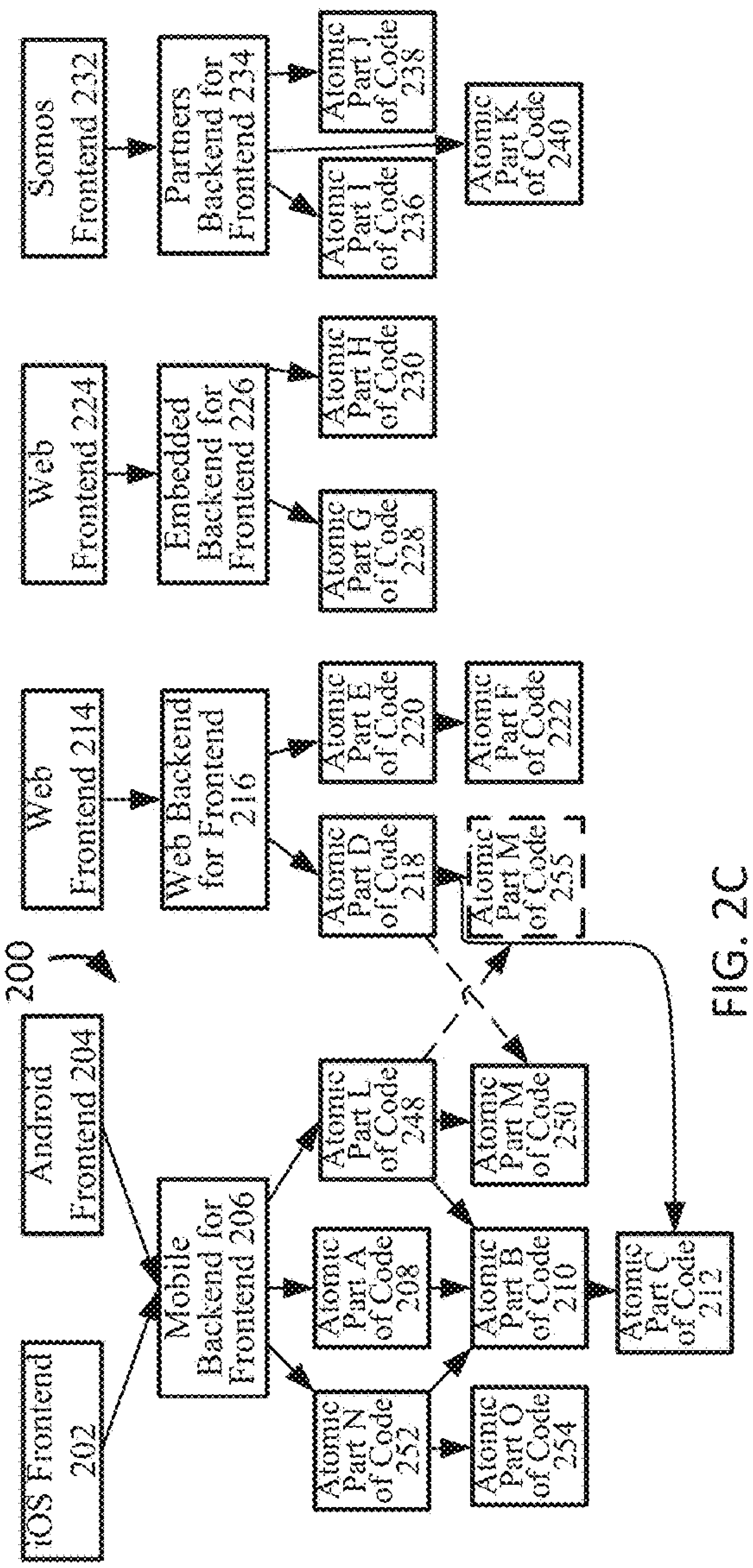
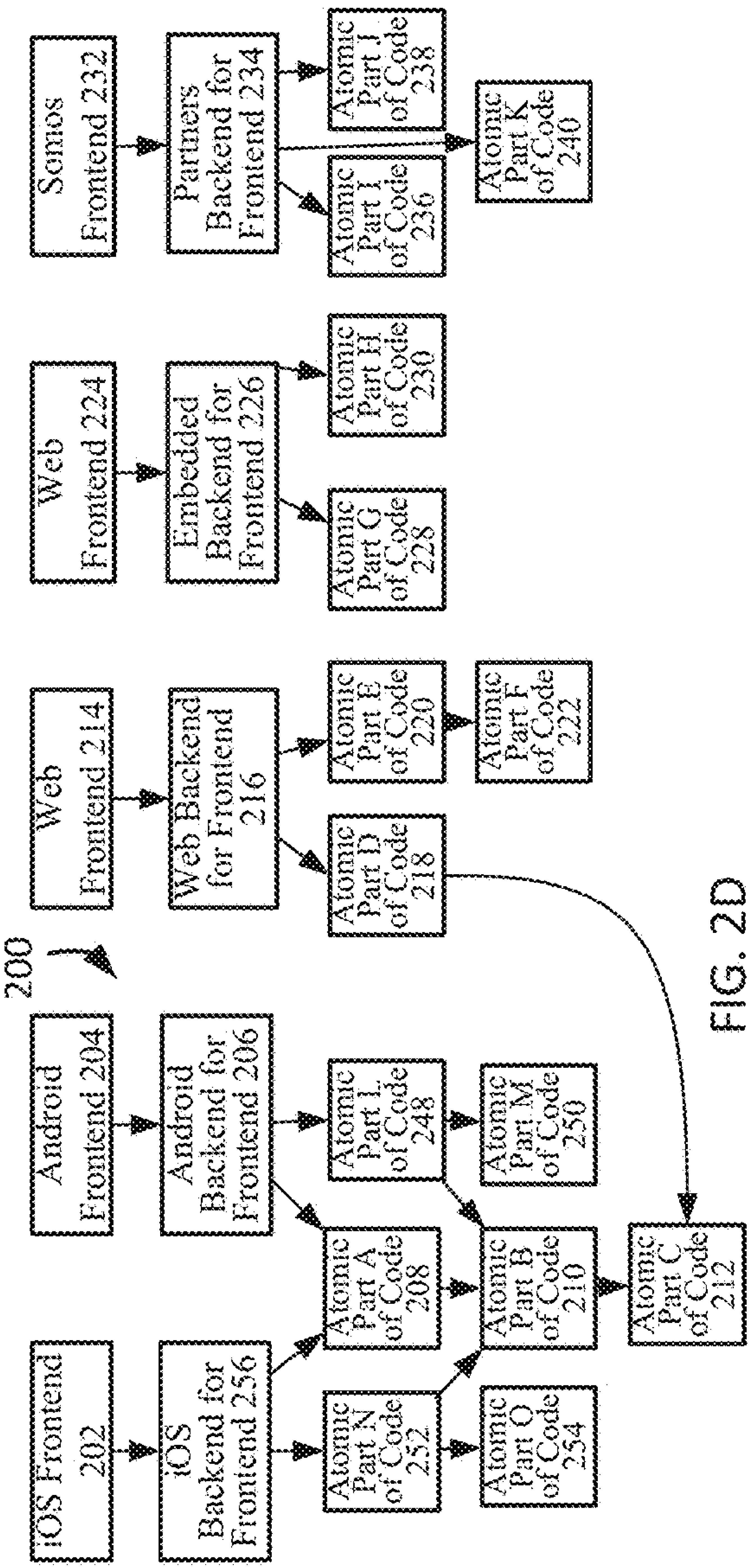

200
iOS Frontend 202
Android Frontend 204
Mobile Backend for Frontend 206
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Web Frontend 214
Web Backend for Frontend 216
Atomic Part D of Code 218
Atomic Part E of Code 220
Atomic Part F of Code 222
Web Frontend 224
Embedded Backend for Frontend 226
Atomic Part G of Code 228
Atomic Part H of Code 230
Somos Frontend 232
Partners Backend for Frontend 234
Atomic Part I of Code 236
Atomic Part J of Code 238
Atomic Part K of Code 240
Atomic Part L of Code 248
Atomic Part M of Code 250
Atomic Part N of Code 252
Atomic Part O of Code 254
Atomic Part M of Code 255

FIG. 2C


200
iOS Frontend 202
iOS Backend for Frontend 256
Android Frontend 204
Android Backend for Frontend 206
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Web Frontend 214
Web Backend for Frontend 216
Atomic Part D of Code 218
Atomic Part E of Code 220
Atomic Part F of Code 222
Web Frontend 224
Embedded Backend for Frontend 226
Atomic Part G of Code 228
Atomic Part H of Code 230
Somos Frontend 232
Partners Backend for Frontend 234
Atomic Part I of Code 236
Atomic Part J of Code 238
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Atomic Part M of Code 250
Atomic Part N of Code 252
Atomic Part O of Code 254

FIG. 2D

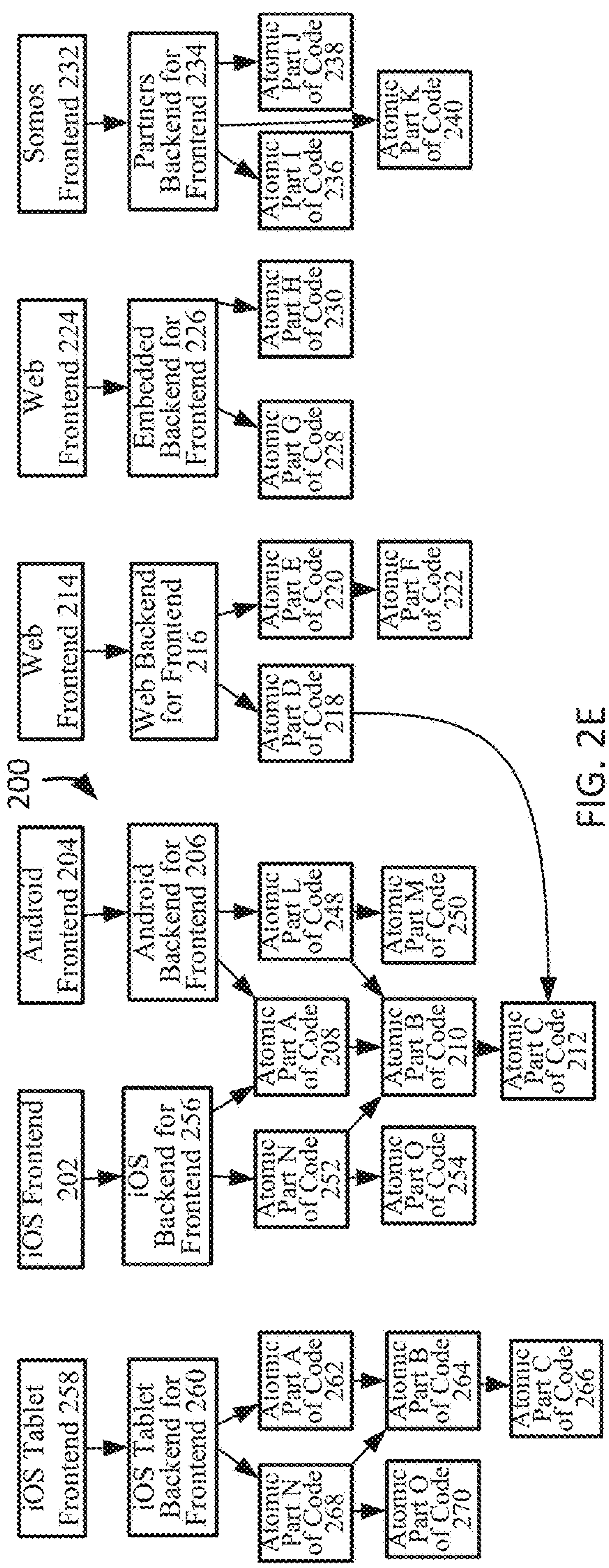
200
iOS Tablet Frontend 258
iOS Frontend 202
Android Frontend 204
Web Frontend 214
Web Frontend 224
Somos Frontend 232
iOS Tablet Backend for Frontend 260
iOS Backend for Frontend 256
Android Backend for Frontend 206
Web Backend for Frontend 216
Embedded Backend for Frontend 226
Partners Backend for Frontend 234
Atomic Part A of Code 262
Atomic Part B of Code 264
Atomic Part C of Code 266
Atomic Part N of Code 268
Atomic Part O of Code 270
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Atomic Part N of Code 252
Atomic Part O of Code 254
Atomic Part L of Code 248
Atomic Part M of Code 250
Atomic Part D of Code 218
Atomic Part E of Code 220
Atomic Part F of Code 222
Atomic Part G of Code 228
Atomic Part H of Code 230
Atomic Part I of Code 236
Atomic Part J of Code 238
Atomic Part K of Code 240

FIG. 2E

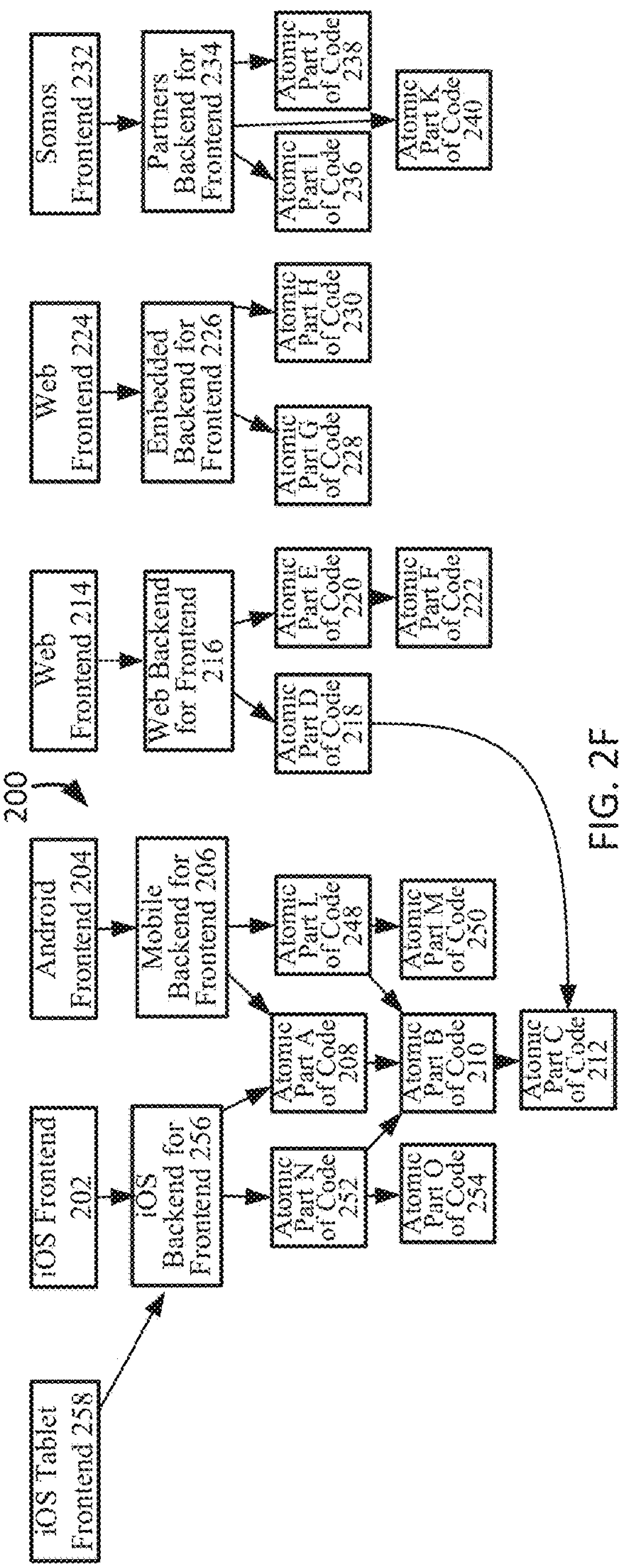
200
iOS Tablet Frontend 258
iOS Frontend 202
Android Frontend 204
Web Frontend 214
Web Frontend 224
Somos Frontend 232
iOS Backend for Frontend 256
Mobile Backend for Frontend 206
Web Backend for Frontend 216
Embedded Backend for Frontend 226
Partners Backend for Frontend 234
Atomic Part N of Code 252
Atomic Part O of Code 254
Atomic Part A of Code 208
Atomic Part B of Code 210
Atomic Part C of Code 212
Atomic Part L of Code 248
Atomic Part M of Code 250
Atomic Part D of Code 218
Atomic Part E of Code 220
Atomic Part F of Code 222
Atomic Part G of Code 228
Atomic Part H of Code 230
Atomic Part I of Code 236
Atomic Part J of Code 238
Atomic Part K of Code 240

FIG. 2F

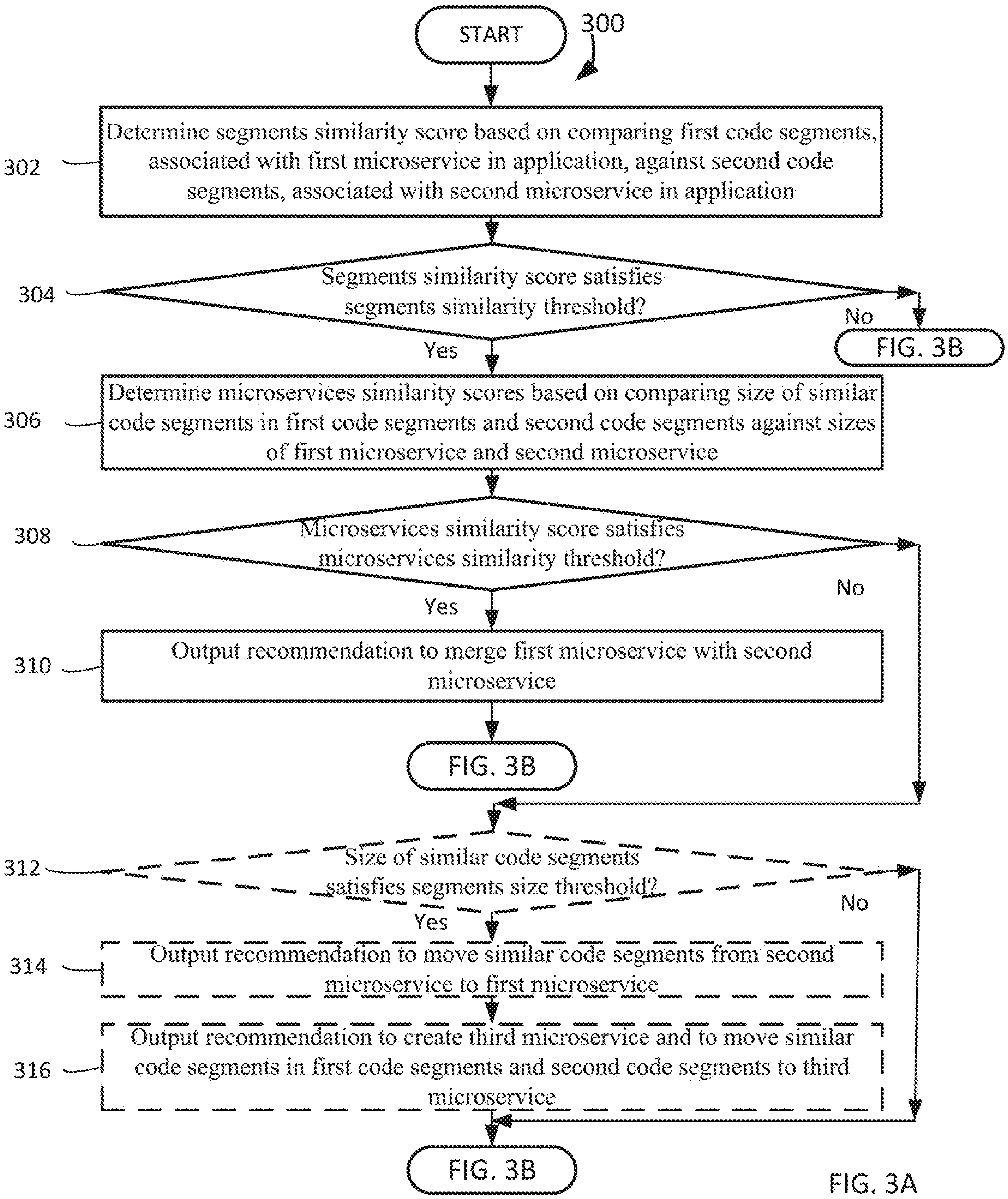
START
300
302
Determine segments similarity score based on comparing first code segments, associated with first microservice in application, against second code segments, associated with second microservice in application
304
Segments similarity score satisfies segments similarity threshold?
No
FIG. 3B
Yes
306
Determine microservices similarity scores based on comparing size of similar code segments in first code segments and second code segments against sizes of first microservice and second microservice
308
Microservices similarity score satisfies microservices similarity threshold?
No
Yes
310
Output recommendation to merge first microservice with second microservice
FIG. 3B
312
Size of similar code segments satisfies segments size threshold?
No
Yes
314
Output recommendation to move similar code segments from second microservice to first microservice
316
Output recommendation to create third microservice and to move similar code segments in first code segments and second code segments to third microservice
FIG. 3B

FIG. 3A

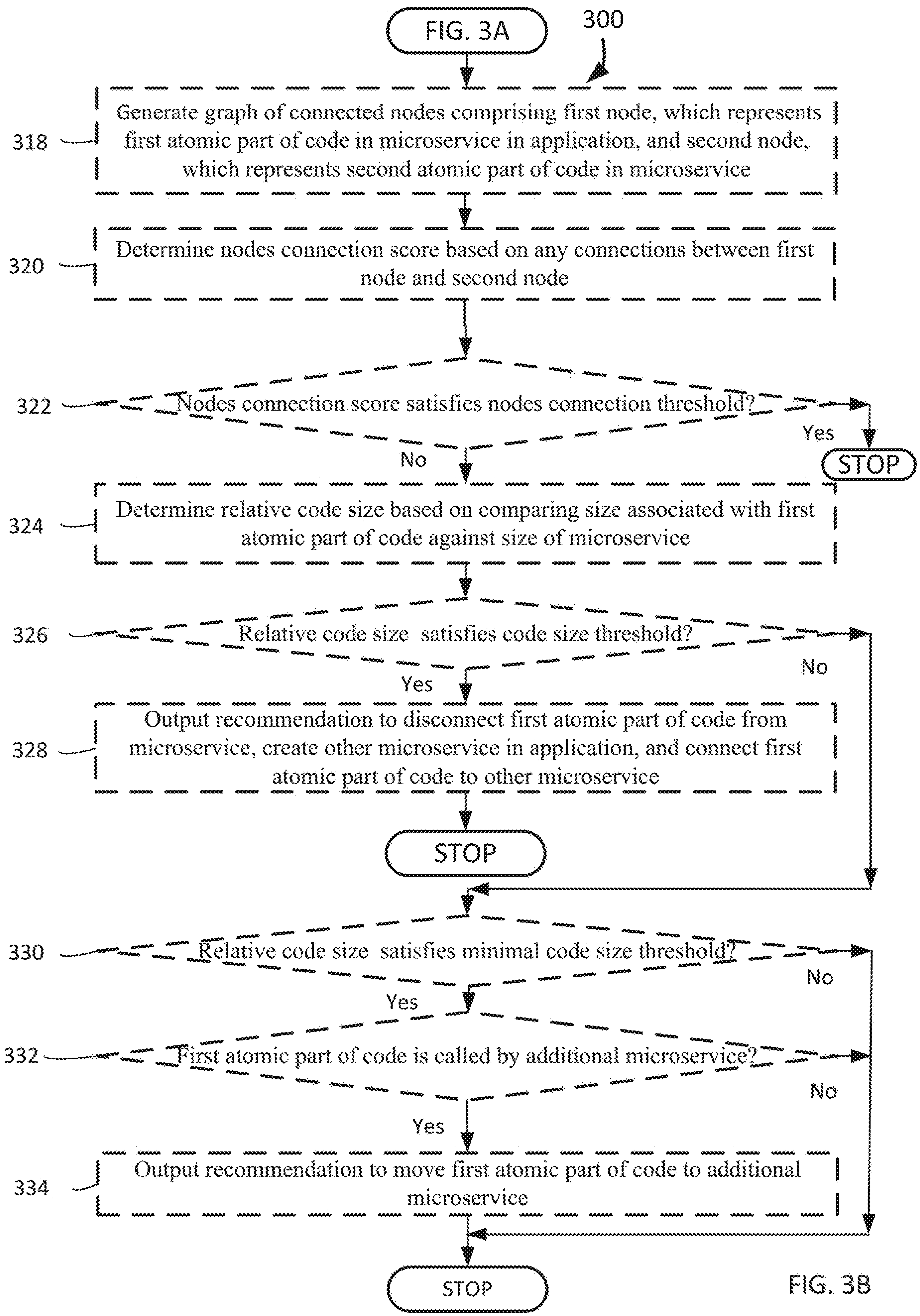
FIG. 3A
300
318
Generate graph of connected nodes comprising first node, which represents first atomic part of code in microservice in application, and second node, which represents second atomic part of code in microservice
320
Determine nodes connection score based on any connections between first node and second node
322
Nodes connection score satisfies nodes connection threshold?
Yes
STOP
No
324
Determine relative code size based on comparing size associated with first atomic part of code against size of microservice
326
Relative code size satisfies code size threshold?
No
Yes
328
Output recommendation to disconnect first atomic part of code from microservice, create other microservice in application, and connect first atomic part of code to other microservice
STOP
330
Relative code size satisfies minimal code size threshold?
No
Yes
332
First atomic part of code is called by additional microservice?
No
Yes
334
Output recommendation to move first atomic part of code to additional microservice
STOP

FIG. 3B

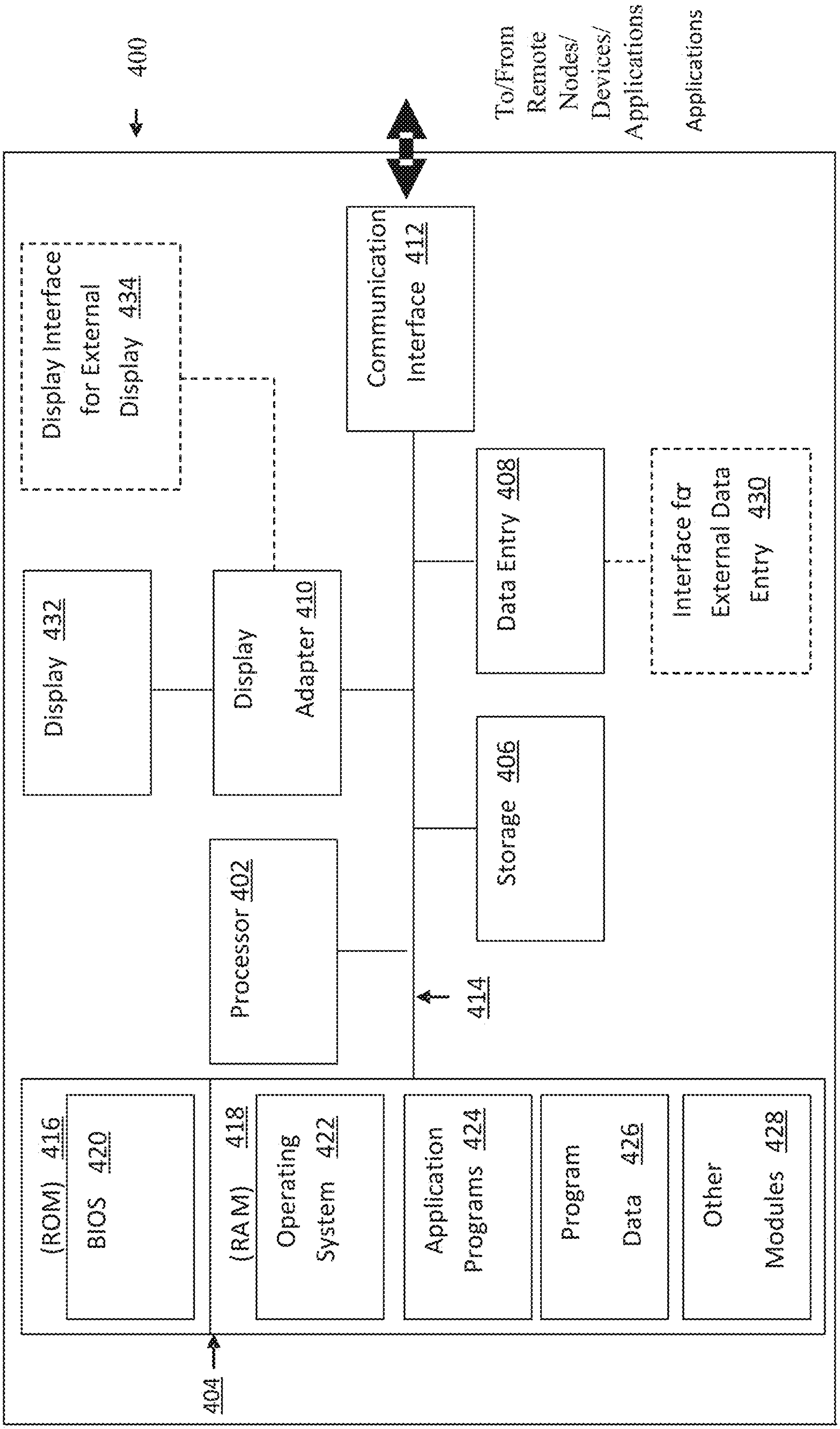
400
To/From Remote Nodes/ Devices/ Applications
Applications
Display Interface for External Display 434
Communication Interface 412
Display 432
Display Adapter 410
Data Entry 408
Interface for External Data Entry 430
Processor 402
Storage 406
414
(ROM) 416
BIOS 420
(RAM) 418
Operating System 422
Application Programs 424
Program Data 426
Other Modules 428
404

FIG. 4

RECOMMENDING THE REFACTORING OF MICROSERVICES

BACKGROUND

Microservices are a software development technique, and a variant of the service-oriented architecture style that structures a software application as a collection of loosely coupled services. In a microservices architecture, the loosely coupled services are fine-grained services and their communication protocols are lightweight. Decomposing an application into smaller services improves modularity, which makes the application easier to understand, develop, and test. This application decomposition parallelizes development by enabling small autonomous teams to develop, deploy, and scale their respective services independently.

Whether a software developer is building a new product or decomposing an existing monolithic application, one of the most difficult problems in adopting a microservices architecture is defining the granularity of each microservice. Defining the correct boundaries, both from the business and the technological aspect, is an error prone process that is extremely difficult to accomplish correctly. This tedious and iterative process can require significant amounts of time and money. As much as a microservices architecture allows agility and quick response to business needs, an evolving microservices architecture requires rethinking, changing the boundaries of existing components, and a process known as refactoring.

Refactoring is the process of restructuring existing computer code—changing the factoring—without changing the computer code's external behavior. Refactoring is intended to improve non-functional attributes of the computer code. Advantages of refactoring include reduced complexity and improved source-code maintainability. Typically, refactoring applies a series of standardized basic micro-refactorings, each of which is usually a tiny change in a computer program's source code that either preserves the behavior of the computer code, or at least does not modify the source code's conformance to functional requirements. Many software development environments provide automated support for performing the mechanical aspects of these basic refactorings. If done well, the refactoring of computer code may help software developers discover and correct hidden bugs or vulnerabilities by simplifying the underlying logic and eliminating unnecessary levels of complexity.

Moreover, when a developer wants to introduce a new concept into an existing system composed of several microservices, the developer needs to decide how to divide the new concept to different parts appropriate for each of the current microservices or conduct a refactoring of the system. The refactoring can generate new microservices which will include computer code for the new concept.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a block diagram of an example system for recommending the refactoring of microservices, under an embodiment;

FIGS. **2**A-F illustrate example graphs for recommending the refactoring of microservices, under an embodiment

FIGS. **3**A-B depict a flowchart that illustrates a method for recommending the refactoring of microservices, under an embodiment; and

FIG. **4** is a block diagram illustrating an example hardware device in which the subject matter may be implemented.

DETAILED DESCRIPTION

Embodiments herein recommend the refactoring of microservices. A system generates a graph of connected nodes including a first node, which represents a first atomic part of code in a microservice in an application, and a second node, which represents a second atomic part of code in the micro service. The system determines a nodes connection score based on any connections between the first node and the second node. If the nodes connection score satisfies a nodes connection threshold, the system determines a relative code size based on comparing a size associated with the first atomic part of code against a size of the micro service. If the relative code size satisfies a code size threshold, the system outputs a recommendation to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice.

For example, a refactoring recommendation tool uses unified modeling language to generate a graph of connected nodes which include nodes that represent an atomic part A of code, an atomic part B of code, an atomic part C of code, an atomic part L of code, an atomic part M of code, an atomic part N of code, and an atomic part O of code for a mobile Backend for Frontend. The refactoring recommendation tool calculates a nodes connection score of 1.00 for the connection between the atomic part L of code and the atomic part M of code, a nodes connection score of 0.50 for the connection between the atomic part L of code and the atomic part C of code, and a nodes connection score of 0.00 for each of the connections between the atomic part L of code and the atomic part N of code, and the atomic part O of code. Since the nodes connection score of 0.00 for each of the connections between the atomic part L of code and the atomic part N of code, and the atomic part O of code do not satisfy a nodes connection threshold of 0.125, the refactoring recommendation tool compares the size of the atomic part N of code and its directly connected atomic part O of code against the size of the mobile Backend for Frontend, which results in a relative code size of 29%. %. Since the relative code size of 29% for the atomic part N of code and its directly connected atomic part O of code is greater than a code size threshold of 20%, the refactoring recommendation tool outputs a recommendation to disconnect the atomic part N of code and its directly connected atomic part O of code from the mobile Backend for Frontend, create a new iOS Backend for Frontend, connect the atomic part N of code and its directly connected atomic part O of code to the new iOS Backend for Frontend, and rename the mobile Backend for Frontend as the Android Backend for Frontend. Splitting the microservice into two microservices can reduce complexity, improve source-code maintainability, and enable software developers to develop code more quickly and efficiently by discovering and correcting hidden bugs or vulnerabilities through simplifying the underlying logic and eliminating unnecessary levels of complexity.

FIG. **1** illustrates a block diagram of a system that implements recommending the refactoring of microservices, under an embodiment. As shown in FIG. **1**, system **100** may illustrate a cloud computing environment in which data, applications, services, and other resources are stored and delivered through shared data-centers and appear as a single point of access for the users. The system **100** may also represent any other type of distributed computer network environment in which servers control the storage and distribution of resources and services for different client users.

In an embodiment, the system **100** represents a cloud computing system that includes a first client **102**, a second client **104**, and a third client **106**; and a first server **108** and a second server **110** that may be provided by a hosting company. Although FIG. **1** depicts the first client **102** as a laptop computer **102**, the second client **104** as a personal computer **104**, and the third client **106** as an Apple® Macintosh computer **106**, each of the clients **102-106** may be any type of computer, such as a server. The clients **102-106** and the servers **108-110** communicate via a network **112**. Any combination of the servers **108-110** may be any combination of physical computers and virtual machines, or virtual servers. Although FIG. **1** depicts the system **100** with three clients **102-106**, two servers **108-110**, and one network **112**, the system **100** may include any number of clients **102-106**, any number of servers **108-110**, and any number of networks **112**. The clients **102-106** and the servers **108-110** may each be substantially similar to the system **400** depicted in FIG. **4** and described below in reference to FIG. **4**.

The first server **108** includes a service application **114** that includes a first microservice **116**, a second microservice **118**, and a third microservice **120**. The first microservice **116** includes first codes segments **122** that include a first atomic part of code **124**, the second microservice **118** includes second codes segments **126** that include a second atomic part of code **128**, and the third microservice **120** includes third codes segments **130** that include a third atomic part of code **132**. The first server **108** also includes a refactoring recommendation tool **134** and a graph **136** that includes connected nodes **138**. FIG. **1** depicts the service application **114** and the refactoring recommendation tool **134** residing completely on the first server **108**, but the service application **114** and/or the refactoring recommendation tool **134** may reside completely on any of the clients **102-106**, completely on the second server **110**, or in any combination of partially on the first server **108**, partially on the clients **102-106**, and partially on the second server **110**. The service application **114** and/or the refactoring recommendation tool **134** may provide a plug-in to any of the clients **102-106** and/or the servers **108-110** that enables any of the clients **102-106** and/or the servers **108-110** to execute the service application **114** and/or the refactoring recommendation tool **134**.

FIGS. **2**A-F illustrate example graphs for recommending the refactoring of microservices, under an embodiment. FIG. **2**A depicts a graph **200** of the service application **114** that includes an iOS frontend **202**, an Android frontend **204**, and their corresponding first microservice **116**, which is a mobile Backend for Frontend **206**. The mobile Backend for Frontend **206** contains the first code segments **122** that include the corresponding first atomic part of code **124**, such as an atomic part A of code **208**, an atomic part B of code **210**, and an atomic part C of code **212**. The graph **200** also includes a web frontend **214** and its corresponding second microservice **118**, which is a web Backend for Frontend **216**. The web Backend for Frontend **216** contains the corresponding second code segments **126** that include the second atomic part of code **128**, such as an atomic part D of code **218**, an atomic part E of code **220**, and an atomic part F of code **222**.

The graph **200** further includes a web frontend **224** and its corresponding third microservice **120**, which is an embedded Backend for Frontend **226**. The embedded Backend for Frontend **226** contains the corresponding third code segments **130** that include the third atomic part of code **132**, such as an atomic part G of code **228** and an atomic part H of code **230**. The graph **200** additionally includes a Somos frontend **232** and its corresponding microservice, which is a partners Backend for Frontend **234**. The partners Backend for Frontend **234** contains code segments that include an atomic part of code, such as an atomic part I of code **236**, an atomic part J of code **238**, and an atomic part K of code **240**. The graph **200** can also include an atomic part C of code **242** for the web Backend for Frontend **216**, a part C Backend for Frontend **244**, and an atomic part C of code **246** for the part C Backend for Frontend **244**.

Microservices can sometimes split due to historical reasons which can change after a while. Additionally, many copy and paste iterations can produce similar microservices. Therefore, if some microservices share enough similar code, these microservices can be merged into one microservice. For example, after the software developer adds the code for the atomic part C of code **242** for the web Backend for Frontend **216**, the refactoring recommendation tool **134** uses a diff utility, which is a line-oriented data comparison tool, to identify similarities in large amounts of code that evolved during development cycles. Similar to the Levenshtein-distance algorithm, the diff utility determines the smallest set of deletions and insertions to create one file that is being compared from another file that is being compared. Therefore, the refactoring recommendation tool **134** uses a diff utility to compare code segments for the mobile Backend for Frontend **206** against code segments for the web Backend for Frontend **216**. The diff utility's comparison of the code segments that include the atomic part A of code **208**, the atomic part B of code **210**, the atomic part D of code **218**, the atomic part E of code **220**, and the atomic part F of code **222** resulted in very low similarity scores that are close to 0.00. However, the diff utility's comparison of the code segments that include the atomic part C of code **212** for the mobile Backend for Frontend **206** against the code segments that include the atomic part C of code **242** for the web Backend for Frontend **216** resulted in a segments similarity score of 0.98. Although these examples use segments similarity scores in the range from 0.00 to 1.00, any range and type of segments similarity score may be used.

An application can be a computer program or piece of software designed and written to fulfill a particular purpose of a user. A microservice can be a loosely coupled service in a software application. A code segment can be a portion of a computer program that contains executable instructions. A segments similarity score can be a number that expresses the resemblance between portions of executable computer instructions.

If none of the segments similarity scores for compared code segments satisfy a segments similarity threshold, the refactoring recommendation tool **134** will not recommend the merging of the microservices that include the compared code segments. A segments similarity threshold can be the magnitude that must be satisfied by a number, which expresses the resemblance between portions of executable computer instructions, for a specific result to occur. Since the segments similarity score of 0.98 for the atomic part C of code **212** and the atomic part C of code **242** satisfies the segments similarity threshold of 0.75, the refactoring recommendation tool **134** determines whether the mobile Backend for Frontend **206** and the web Backend for Frontend **216** share enough similar code segments to justify being merged into a single microservice. Although this example uses a segments similarity threshold in the range from 0.00 to 1.00, any range and type of segments similarity threshold may be used.

Continuing the example, the refactoring recommendation tool **134** compares the size of the identified similar code segments in the mobile Backend for Frontend **206** and the web Backend for Frontend **216** against the sizes of mobile Backend for Frontend **206** and the web Backend for Frontend **216** to determine whether the mobile backend for frontend **206** and the web Backend for Frontend **216** share enough similar code segments to justify being merged into a single microservice. This comparison of the size of the similar code segments to the sizes of their microservices results in microservices similarity scores of 0.33 for the mobile Backend for Frontend **206** and 0.25 for the web Backend for Frontend **216**, which indicates that the similar code segments are only 33% of one microservice and 25% of the other microservice. Although these examples use microservices similarity scores in the range from 0.00 to 1.00, any range and type of microservices similarity scores may be used. A size can be the overall dimensions or magnitude of a thing. A microservices similarity score can be a number that expresses the resemblance between loosely coupled services in a software application.

If any of the microservices similarity scores for the microservices satisfy a microservices similarity threshold, the refactoring recommendation tool **134** will recommend the merging of the microservices that include the compared code segments. A microservices similarity threshold can be the magnitude that must be satisfied by a number, which expresses the resemblance between loosely coupled services in a software application, for a specific result to occur. Since neither the microservices similarity score of 0.33 for the mobile Backend for Frontend **206** nor the microservices similarity score of 0.25 for the web Backend for Frontend **216** satisfies the microservices similarity threshold of 0.80, these microservices do not share enough similar code segments to justify being merged into a single microservice. Consequently, the refactoring recommendation tool **134** determines if the similar code segments are sufficiently large to justify being moved by determining whether the size of the similar code segments in the atomic part C of code **212** and the atomic part C of code **242** satisfy a segments size threshold. A segments size threshold can be the magnitude that must be satisfied by a number, which is the overall dimensions or magnitude of a portion of a computer program that contains executable instructions, for a specific result to occur.

If the size of the similar code segments does not satisfy the segments size threshold, the similar segments are too small to justify being moved, and the refactoring recommendation tool **134** can evaluate whether sizes of other similar code segments satisfy the segments size threshold. If the size of the similar code segments satisfies the segments size threshold, the refactoring recommendation tool **134** can output a recommendation to move one set of the similar code segments from one microservice to the other microservice that includes the other set of similar code segments. For example, the refactoring recommendation tool **134** outputs a recommendation to move the atomic part C of code **242** from the web Backend for Frontend **216** to the atomic part C of code **212** for the mobile Backend for Frontend **206** by linking the atomic part D of code **218** to the merged atomic part C of code **212** and deleting the atomic part C of code **242**, as depicted by FIG. **2**A. A recommendation can be a proposal as to the best course of action.

Alternatively, if the size of the similar code segments satisfies the segments size threshold, the refactoring recommendation tool **134** can output a recommendation to create a new microservice and to move the similar code segments to the new microservice. For example, since the refactoring recommendation tool **134** calculates that only 14% of the code for the mobile Backend for Frontend **206** is dedicated to the atomic part C of code **212**, and only 25% of the code for the web Backend for Frontend **216** is dedicated to the atomic part C of code **242**, none of the existing microservices is sufficiently dedicated to the similar code segments. Therefore, the refactoring recommendation tool **134** outputs a recommendation to create the part C Backend for Frontend **244**, and to move the atomic part C of code **212** from the mobile Backend for Frontend **206** and the atomic part C of code **242** from the web Backend for Frontend **216** to become the atomic part C of code **246** for the part C Backend for Frontend **244**. In this situation, the Android frontend **206** and the web frontend **214** would both be linked to the part C Backend for Frontend **244**.

FIG. **2**B depicts the graph **200**, which indicates that a software developer added an atomic part L of code **248** and an atomic part M of code **250** to the mobile Backend for Frontend **206** to provide additional functionality exclusively for the Android frontend **204**. FIG. **2**C depicts the graph **200**, which indicates that a software developer added an atomic part N of code **252** and an atomic part O of code **254** to the mobile Backend for Frontend **206** to provide additional functionality exclusively for the iOS frontend **202**. These example additions of code demonstrate that during the evolution of a microservice, part of the microservice may grow large and complex while other parts of the microservice may remain small or just separate from the large part of the microservice. When two or more parts of a microservice are not strongly connected anymore, splitting the microservice into smaller parts may reduce complexity, improve source-code maintainability, and enable software developers to discover and correct hidden bugs or vulnerabilities by simplifying the underlying logic and eliminating unnecessary levels of complexity. For example, the code that the software developer added to the mobile Backend for Frontend **206** to provide added functionality exclusively for the iOS frontend **202** is very different from the code that the software developer added to the mobile Backend for Frontend **206** to provide added functionality exclusively for the Android frontend **204**.

The refactoring recommendation tool **134** can identify such differing code in the mobile Backend for Frontend **206** by using unified modeling language to generate the graph **200** of connected nodes depicted by FIG. **2**C, which include nodes that represent the atomic part A of code **208**, the atomic part B of code **210**, the atomic part C of code **212**, the atomic part L of code **248**, the atomic part M of code **250**, the atomic part N of code **252**, and the atomic part O of code **254**. A graph can be a diagram representing a system of connections among things. A node can be a point at which lines or pathways intersect or branch. A connected node can be a point at which lines or pathways intersect or branch. An atomic part of code can be a functionally irreducible portion of a computer program that contains executable instructions.

If some parts of a microservice have evolved differently from other parts, an analysis of a graph that represents the parts of the microservice can determine the parts that are disconnected. Alternatively, algorithms such as the Girvan-Newman algorithm can find groups of parts in a graph that are more densely connected, which may be referred to as graph communities, while other groups of parts are sparsely connected. For example, the refactoring recommendation tool **134** uses graph analysis to determine that the flow of the mobile Backend for Frontend **206** which executes the atomic part L of code **248** can subsequently execute the atomic part

M of code **250**, the atomic part B of code **210**, and the atomic part C of code **212**, but can never subsequently execute the atomic part A of code **208**, the atomic part N of code **252**, or the atomic part O of code **254**. This graph analysis determines that the atomic part L of code **248** is directly connected to the atomic part M of code **250** and the atomic part B of code **210**, is indirectly connected to the atomic part C of code **212**, and is disconnected from the atomic part A of code **208**, the atomic part N of code **252**, and the atomic part O of code **254**. Therefore, the refactoring recommendation tool **134** calculates a nodes connection score of 1.00 for the connection between the atomic part L of code **248** and the atomic part M of code **250**, calculates a nodes connection score of 0.50 for the connection between the atomic part L of code **248** and the atomic part C of code **212**, and calculates a nodes connection score of 0.00 for each of the connections between the atomic part L of code **248** and the atomic part A of code **208**, the atomic part N of code **252**, and the atomic part O of code **254**.

The graph analysis also determines that the flow of the mobile Backend for Frontend **206** which executes the atomic part N of code **252** can subsequently execute the atomic part O of code **254** and the atomic part C of code **212**, but can never subsequently execute the atomic part A of code **208**, the atomic part L of code **248**, or the atomic part M of code **250**. This graph analysis determines that the atomic part N of code **252** is directly connected to the atomic part O of code **254** and the atomic part B of code **210**, is indirectly connected to the atomic part C of code **212**, and is disconnected from the atomic part A of code **208**, the atomic part L of code **248**, and the atomic part M of code **250**. Therefore, the refactoring recommendation tool **134** calculates a nodes connection score of 1.00 for each of the connections between the atomic part N of code **252** and the atomic part O of code **254**, and the atomic part B of code **210**, calculates a nodes connection score of 0.50 for the connection between the atomic part N of code **252** and the atomic part C of code **212**, and calculates a nodes connection score of 0.00 for each of the connections between the atomic part N of code **252** and the atomic part A of code **208**, the atomic part L of code **248**, and the atomic part M of code **250**.

Collectively, the nodes connection scores identify the disconnected parts of a microservice, which indicate that the atomic part A of code **208**, the atomic part L of code **248**, and the atomic part N of code **252** are the beginnings of three alternative flows for the mobile Backend for Frontend **206**, and that the atomic part L of code **248** and the atomic part M of code **250** are disconnected from the atomic part N of code **252** and the atomic part O of code **254**. The graph analysis produces nodes connection scores which reflect that the mobile Backend for Frontend **206** executes the atomic part L of code **248** and the atomic part M of code **250** exclusively for the Android frontend **204**, and also executes the atomic part N of code **252** and the atomic part O of code **254** exclusively for the iOS frontend **202**. A connection can be the way in which multiple objects are linked. A nodes connection score can be a number that expresses the way in which multiple objects are linked. Although these examples use nodes connection scores in the range from 0.00 to 1.00, any range and type of nodes connection scores may be used.

Then the refactoring recommendation tool **134** determines whether each atomic part of code in the mobile Backend for Frontend **206** is sufficiently connected by determining whether each of the nodes connection scores satisfies a nodes connection threshold of 0.125. A nodes connection threshold can be the magnitude that must be satisfied by a number, which expresses the way in which multiple objects are linked, for a specific result to occur. If a nodes connection score satisfies the nodes connection threshold, the corresponding nodes are sufficiently connected, and the refactoring recommendation tool **134** can evaluate whether other nodes connection scores satisfy the nodes connection threshold. However, if a nodes connection score does not satisfy the nodes connection threshold, the corresponding nodes are insufficiently connected, so the refactoring recommendation tool **134** calculates the relative sizes of insufficiently connected nodes to determine whether the insufficiently connected nodes are sufficiently large to justify a split in their microservice.

For example, since each of the atomic part L of code **248** and its directly connected atomic part M of code **250** have an insufficient nodes connection score of 0.0 to each of the atomic part N of code **252** and its directly connected atomic part O of code **254**, the refactoring recommendation tool **134** compares the size of the atomic part L of code **248** and its directly connected atomic part M of code **250** against the size of the mobile Backend for Frontend **206**, which results in a relative code size of 28%. In another example, since each of the atomic part N of code **252** and its directly connected atomic part O of code **254** have an insufficient nodes connection score of 0.0 to each of the atomic part L of code **248** and its directly connected atomic part M of code **250**, the refactoring recommendation tool **134** compares the size of the atomic part N of code **252** and its directly connected atomic part O of code **254** against the size of the mobile Backend for Frontend **206**, which results in a relative code size of 29%. A relative code size can be a number that expresses the proportional dimensions or magnitude of a portion of a computer program that contains executable instructions compared to dimensions or magnitude of another portion of the computer program that contains executable instructions. Although these examples use relative code sizes in the range from 0% to 100%, any range and type of relative code sizes may be used.

The refactoring recommendation tool **134** determines whether the insufficiently connected nodes are sufficiently large to justify a split in their microservice by determining whether their relative code size satisfies a code size threshold. In another example, the refactoring recommendation tool **134** compares the relative code size of 28% for the atomic part L of code **248** and its directly connected atomic part M of code **250** against the code size threshold of 20%. In another example, the refactoring recommendation tool **134** compares the relative code size of 29% for the atomic part N of code **252** and its directly connected atomic part O of code **254** against the code size threshold of 20%. A code size threshold can be the magnitude that must be satisfied by a number, which expresses the relative dimensions or magnitude of a portion of a computer program that contains executable instructions, for a specific result to occur. If a relative code size does not satisfy the code size threshold, the refactoring recommendation tool **134** can evaluate whether other relative code sizes satisfy the code size threshold required for recommending a split in a microservice. Although these examples use code size thresholds in the range from 0% to 100%, any range and type of code size thresholds may be used.

If a relative code size satisfies the code size threshold, the refactoring recommendation tool **134** can output a recommendation to split a microservice by disconnecting any insufficiently connected atomic parts of code from the microservice, creating another microservice in the application, and connecting any disconnected atomic parts of code to the other microservice. For example, since the relative code size of 29% for the atomic part N of code **252** and its directly connected atomic part O of code **254** satisfy the code size threshold of 20%, the refactoring recommendation tool **134** outputs a recommendation to refactor a microservice by splitting the microservice. The recommendation is to disconnect the atomic part N of code **252** and its directly connected atomic part O of code **254** from the mobile Backend for Frontend **206**, create a new iOS Backend for Frontend **256**, connect the atomic part N of code **252** and its directly connected atomic part O of code **254** to the new iOS Backend for Frontend **256**, and rename the mobile Backend for Frontend **206** as the Android Backend for Frontend **206**. The recommendation also includes linking the new iOS Backend for Frontend **256** to the atomic part A of code **208**, which creates indirect connections to the atomic part B of code **210** and the atomic part C of code **212**, as depicted in FIG. **2**D. Splitting the microservice into two microservices can reduce complexity, improve source-code maintainability, and enable software developers to develop code more quickly and efficiently by discovering and correcting hidden bugs or vulnerabilities through simplifying the underlying logic and eliminating unnecessary levels of complexity.

FIG. **2**D depicts that the Android Backend for Frontend **206** includes the atomic part A of code **208**, the atomic part B of code **210**, and the atomic part C of code **212** along with the atomic part L of code **248** and the atomic part M of code **250**, which are densely connected for the Android frontend **204**. Similarly, the new iOS Backend for Frontend **256** includes the atomic part A of code **208**, the atomic part B of code **210**, and the atomic part C of code **212** along with the atomic part N of code **252** and the atomic part O of code **254**, which are densely connected for the iOS frontend **202**.

In an alternative example, the graph **200** depicted by FIG. **2**C indicates that a software developer added the atomic part N of code **252**, the atomic part O of code **254**, and the atomic part L of code **248** to the mobile Backend for Frontend **206** to provide additional functionality for both the iOS frontend **202** and the Android frontend **204**. The graph **200** depicted by FIG. **2**C also indicates that a software developer added the atomic part M of code **250** to the mobile Backend for Frontend **206** to provide additional functionality exclusively for the Android frontend **204** and the web frontend **214**. Therefore, the refactoring recommendation tool **134** calculates a nodes connection score of 1.00 for the connection between the atomic part L of code **248** and the atomic part M of code **250**, a nodes connection score of 0.00 for the connection between the atomic part N of code **252** and the atomic part M of code **250**, and a nodes connection score of 0.00 for the connection between the atomic part O of code **254** and the atomic part M of code **250**. The atomic part N of code **252** and its directly connected atomic part O of code **254** each have a nodes connection score of 0.00 for the atomic part M of code **250**, which is less than the nodes connection threshold of 0.125.

Therefore, the refactoring recommendation tool **134** determines whether the atomic part M of code **250** is large enough to justify splitting the mobile Backend for Frontend **206** by comparing the size of the atomic part M of code **250** against the size of the mobile Backend for Frontend **206**, which results in a relative code size of 14%. Since the relative code size of 14% does not satisfy the code size threshold of 20%, the atomic part M of code **250** is not large enough to justify splitting the mobile Backend for Frontend **206**. Consequently, the refactoring recommendation tool **134** determines if the atomic part M of code **250** is sufficiently large to justify being moved by determining whether the relative code size of 14% satisfies the minimal code size threshold of 10%. Since the relative code size of 14% satisfies the minimal code size threshold of 10%, the refactoring recommendation tool **134** determines whether the atomic part M of code **250** is called by an additional microservice.

Since the atomic part M of code **250** is called by the web Backend for Frontend **216**, the refactoring recommendation tool **134** determines whether to move the loosely connected atomic part M of code **250** from the mobile Backend for Frontend **206** to the calling web Backend for Frontend **216**. The refactoring recommendation tool **134** can determine whether such a move is justified by evaluating whether the mobile Backend for Frontend **206** is more dedicated to the loosely connected atomic part M of code **250** than the calling web Backend for Frontend **216** would be dedicated to a moved version of the connected atomic part M of code **250**. The refactoring recommendation tool **134** evaluates each microservice's dedication to the code that may be moved by calculating the dedication of the mobile Backend for Frontend **206** to the loosely connected atomic part M of code **250** as the relative code size of 0.14, and calculating the dedication of the web Backend for Frontend **216** to a moved version of the atomic part M of code **250** as the relative code size of 0.25. Since a significantly greater percentage of the web Backend for Frontend **216** would be dedicated to a moved version of the atomic part M of code **250** than the percentage of the mobile Backend for Frontend **206** that is currently dedicated to the atomic part M of code **250**, the move of the atomic part M of code **250** to the web Backend for Frontend **216** is justified.

Therefore, the refactoring recommendation tool **134** outputs a recommendation to move the atomic part M of code **250** to the web Backend for Frontend **216**, thereby becoming the moved atomic part M of code **255**, and to add a link that enables the mobile Backend for Frontend **206** to call the moved atomic part M of code **255**. A minimal code size threshold can be the magnitude that must be satisfied by a number, which expresses the relative dimensions or magnitude of a portion of a computer program that, contains executable instructions, for a specific result to occur. Although these examples use a minimal code size threshold in the range from 0% to 100%, any range and type of minimal code size threshold may be used.

FIG. **2**E depicts the graph **200**, which indicates that a software developer received a new request to support the iOS tablet in addition to supporting the iOS mobile device. From past experience the software developer decides to add an iOS tablet frontend **258** and code that is structured as its corresponding microservice, an iOS tablet Backend for Frontend **260**. The iOS tablet Backend for Frontend **260** contains code segments that include at least one corresponding atomic part of code, such as an atomic part A of code **262**, an atomic part B of code **264**, an atomic part C of code **266**, an atomic part N of code **268**, and an atomic part O of code **270**.

After the software developer adds the code for an iOS tablet, the refactoring recommendation tool **134** uses a diff utility to compare all code segments for all microservices, including the code segments for the iOS Tablet Backend for Frontend **260** against code segments for the application's iOS Backend for Frontend **256**, which results in a segments similarity score of 0.98. If the segments similarity score of does not satisfy a segments similarity threshold, the refactoring recommendation tool **134** will not recommend the merging of the microservices that include the compared code segments. Since the segments similarity score of 0.98 satisfies the segments similarity threshold of 0.75, the refactoring recommendation tool **134** determines whether the iOS Tablet Backend for Frontend **260** and the iOS Backend for Frontend **256** share enough similar code segments to be merged into a single microservice. For example, the refactoring recommendation tool **134** compares the size of the similar code segments in the iOS Tablet Backend for Frontend **260** and the iOS Backend for Frontend **256** against the sizes of the iOS Tablet Backend for Frontend **260** and the iOS Backend for Frontend **256**, which results in microservices similarity scores of 1.00 for the iOS Tablet Backend for Frontend **260** and 1.00 for the iOS Backend for Frontend **256**.

Although this example describes calculating the same microservices similarity scores for each microservice, the refactoring recommendation tool **134** can calculate different microservices similarity scores for each microservice, and then use the different scores to determine how the microservices are merged. In an alternative example, the refactoring recommendation tool **134** compares the size of similar code in the iOS Tablet Backend for Frontend **260** and the mobile Backend for Frontend **206** against the sizes of the iOS Tablet Backend for Frontend **260** and the mobile Backend for Frontend **206** to calculate a microservices similarity score of 1.00 for the iOS Tablet Backend for Frontend **260** and calculate a microservices similarity score of 0.71 for the mobile Backend for Frontend **206**. Continuing this alternative example, the refactoring recommendation tool **134** recommends merging the iOS Tablet Backend for Frontend **260** into the mobile Backend for Frontend **206** because the similar code segments comprise all of the code in the iOS Tablet Backend for Frontend **260** but comprise only a portion of the code in the mobile Backend for Frontend **206**.

If each of the microservices similarity scores for the microservices do not satisfy a microservices similarity threshold, the refactoring recommendation tool **134** will not recommend the merging of the micro services that include the compared code segments. Since the microservices similarity score of 1.00 for the iOS Tablet Backend for Frontend **260** satisfies the microservices similarity threshold of 0.80, the refactoring recommendation tool **134** outputs a recommendation to merge the iOS Tablet Backend for Frontend **260** into the iOS Backend for Frontend **256**. Merging microservices reduces memory requirements for the application, which reduces operational expenses. Merging can be combining to form a single entity. FIG. **2**F depicts the graph **200**, which indicates that a software developer merged the iOS Tablet Backend for Frontend **260** into the iOS Backend for Frontend **256**, thereby deleting the duplicated atomic parts of code, such as the atomic part A of code **262**, the atomic part B of code **264**, the atomic part C of code **266**, the atomic part N of code **268**, and the atomic part O of code **270**.

FIGS. **3**A-B depict a flowchart that illustrates a method for recommending the refactoring of microservices, under an embodiment. Flowchart **300** illustrates method acts illustrated as flowchart blocks for certain steps involved in and/or between the clients **102-106** and/or the servers **108-110** of FIG. **1**.

A segments similarity score is optionally determined based on comparing first code segments, associated with a first microservice in an application, against second code segments, associated with a second microservice in the application, block **302**. The system can search for similar code segments in different microservices. For example, and without limitation, this can include the refactoring recommendation tool **134** using a diff utility to compare code segments for the iOS Tablet Backend for Frontend **260** against code segments for the application's iOS Backend for Frontend **256**, which results in a segments similarity score of 0.98.

After calculating a segments similarity score, a determination is optionally made whether the segments similarity score satisfies a segments similarity threshold. block **304**. The system can determine whether code segments are sufficiently similar for merging. By way of example and without limitation, this can include the refactoring recommendation tool **134** determining whether the segments similarity score of 0.98 satisfies the segments similarity threshold of 0.75. If the segments similarity score satisfies the segments similarity threshold, then the method **300** continues to block **304** to evaluate the relative sizes of the similar code segments. If the segments similarity score does not satisfy the segments similarity threshold, the method **300** proceeds to FIG. **3**B to evaluate whether any microservices should be split.

If a segments similarity score satisfies a segments similarity threshold, microservices similarity scores are optionally determined based on comparing a size of similar code segments in the first code segments and the second code segments against sizes of the first microservice and the second microservice, block **306**. The system can determine the sizes of the similar code segments relative to the sizes of their microservices. In embodiments, this can include the refactoring recommendation tool **134** comparing the sizes of the similar code segments in the iOS Tablet Backend for Frontend **260** and the iOS Backend for Frontend **256** against the sizes of the iOS Tablet Backend for Frontend **260** and the iOS Backend for Frontend **256**, which results in microservices similarity scores of 1.00 for the iOS Tablet Backend for Frontend **260** and 1.00 for the iOS Backend for Frontend **256**.

Following the calculation of microservices similarity scores, a determination is optionally made whether any microservices similarity score satisfies a microservice similarity threshold, block **308**. The system can determine whether the similar code segments are large enough for merging their microservices. For example, and without limitation, this can include the refactoring recommendation tool **134** determining whether the microservices similarity score of 1.00 for the iOS Tablet Backend for Frontend **260** satisfies the microservices similarity threshold of 0.80. If any microservices similarity score satisfies the microservices similarity threshold, then the method **300** continues to block **310** to recommend the merging of the microservices with the similar code segments. If no microservices similarity score satisfies the microservices similarity threshold, the method **300** proceeds to block **312** to evaluate whether any microservices should be moved.

If any microservices similarity score satisfies the microservices similarity threshold, a recommendation to merge the first microservice with the second microservice is optionally output, block **310**. The system can recommend merging microservices with large amounts of similar code. By way of example and without limitation, this can include the refactoring recommendation tool **134** outputting a recommendation to merge the iOS Tablet Backend for Frontend **260** into the iOS Backend for Frontend **256**, because the microservices similarity score of 1.00 for the iOS Tablet Backend for Frontend **260** satisfies the microservices similarity threshold of 0.80. Then the method **300** proceeds to FIG. **3**B to evaluate whether any microservices should be split.

If no microservices similarity score satisfies a microservices similarity threshold, a determination is optionally made whether the size of similar code segments satisfies a segments size threshold, block **312**. The system can determine if the similar code segments are sufficiently large to be moved. In embodiments, this can include the refactoring recommendation tool **134** determining whether the size of similar code segments in the atomic part C of code **212** and the atomic part C of code **242** satisfies the segments size threshold.

If the size of similar code segments satisfies a segments size threshold, a recommendation is optionally output to move the similar code segments from the second microservice to the first microservice, block **314**. The system can recommend moving sufficiently large and similar code segments. For example, and without limitation, this can include the refactoring recommendation tool **134** outputting a recommendation to move the atomic part C of code **242** from the web Backend for Frontend **216** to the atomic part C of code **212** for the mobile Backend for Frontend **206**, by linking the atomic part D of code **218** to the merged atomic part C of code **212** and deleting the atomic part C of code **242**, as depicted by FIG. **2**C.

If the size of similar code segments satisfies a segments size threshold, a recommendation is optionally output to create a third microservice and to move the similar code segments in the first code segments and the second code segments to the third microservice, block **316**. The system can recommend moving sufficiently large and similar code segments. By way of example and without limitation, this can include the refactoring recommendation tool **134** outputting a recommendation to create the part C Backend for Frontend **244**, and to move the atomic part C of code **212** from the mobile Backend for Frontend **206** and the atomic part C of code **242** from the web Backend for Frontend **216** to become the atomic part C of code **242** for the part C Backend for Frontend **244**. Then the method **300** proceeds to FIG. **3**B to evaluate whether any microservices should be split.

In addition to optionally recommending the merging of microservices that have sufficiently large and similar code segments, a graph of connected nodes is generated, comprising a first node, which represents a first atomic part of code in a microservice in the application, and a second node, which represents a second atomic part of code in the microservice, block **318**. The system generates graphs to identify microservices that should be split. In embodiments, this can include the refactoring recommendation tool **134** using unified modeling language to generate the graph of connected nodes depicted by FIG. **2**C, which include nodes that represent the atomic part A of code **208**, the atomic part B of code **210**, the atomic part C of code **212**, the atomic part L of code **248**, the atomic part M of code **250**, the atomic part N of code **252**, and the atomic part O of code **254** for the mobile Backend for Frontend **206**.

After a graph is generated, a nodes connection score is determined based on any connections between the first node and the second node, block **320**. The system evaluates the connections between parts of microservices. For example, and without limitation, this can include the refactoring recommendation tool **134** calculating a nodes connection score of 1.00 for the connection between the atomic part L of code **248** and the atomic part M of code **250**, calculating a nodes connection score of 0.50 for the connection between the atomic part L of code **248** and the atomic part C of code **212**, and calculating a nodes connection score of 0.00 for each of the connections between the atomic part L of code **248** and the atomic part A of code **208**, the atomic part N of code **252**, and the atomic part O of code **254**.

Following the calculation of the nodes connection score, a determination is made whether the nodes connection score satisfies a nodes connection threshold, block **322**. The system identifies loosely connected parts of microservices. By way of example and without limitation, this can include the refactoring recommendation tool **134** determining whether each atomic part of code in the mobile Backend for Frontend **206** is sufficiently connected by determining whether each of their nodes connection scores satisfies a nodes connection threshold of 0.125. If a nodes connection score does not satisfy a nodes connection threshold, the method **300** continues to block **324** to calculate the relative size of the corresponding atomic part of the code. If a nodes connection score satisfies a nodes connection threshold, the refactoring recommendation tool **134** stops if no other nodes connection scores remain to be evaluated.

If a nodes connection score does not satisfy a nodes connection threshold, a relative code size is determined based on comparing a size associated with the first atomic part of code against the size of the microservice, block **324**. The system determines the relative sizes of loosely connected parts of microservices. In embodiments, this can include the refactoring recommendation tool **134** comparing the size of the atomic part N of code **252** and its directly connected atomic part O of code **254** against the size of the mobile Backend for Frontend **206**, which results in a relative code size of 29%.

Having calculated a relative code size, a determination is made whether the relative code size satisfies a code size threshold, block **326**. The system determines whether the loosely connected parts of microservices are large enough to justify splitting a microservice. For example, and without limitation, this can include the refactoring recommendation tool **134** comparing the relative code size of 29% for the atomic part N of code **252** and its directly connected atomic part O of code **254** against the code size threshold of 20%. If the relative code size satisfies the code size threshold, the method **300** continues to block **328** to recommend the splitting of a microservice. If the relative code size does not satisfy the code size threshold, the method **300** proceeds to block **330** to evaluate whether the corresponding atomic part of code is large enough to be moved.

If a relative code size satisfies a code size threshold, a recommendation is made to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice, block **328**. The system recommends the splitting of microservices. By way of example and without limitation, this can include the refactoring recommendation tool **134** outputting a recommendation to disconnect the atomic part N of code **252** and its directly connected atomic part O of code **254** from the mobile Backend for Frontend **206**, create a new iOS Backend for Frontend **256**, connect the atomic part N of code **252** and its directly connected atomic part O of code **254** to the new iOS Backend for Frontend **256**, and rename the mobile Backend for Frontend **206** as the Android Backend for Frontend **206**. Then the method **300** stops. Splitting the microservice into two microservices can reduce complexity, improve source-code maintainability, and enable software developers to develop code more quickly and efficiently by discovering and correcting hidden bugs or vulnerabilities through simplifying the underlying logic and eliminating unnecessary levels of complexity.

If a relative code size does not satisfy a code size threshold, a determination is optionally made whether the relative code size satisfies a minimal code size threshold, block **330**. The system can determine whether small loosely connected parts of a microservice are still large enough to be moved. In embodiments, this can include the refactoring recommendation tool **134** determining whether the relative code size of 14% satisfies the minimal code size threshold of 10%. If the relative code size satisfies the minimal code size threshold, the method **300** continues to block **332** to determine whether the corresponding atomic part of code is called by another microservice. If the relative code size does not satisfy the minimal code size threshold, the method **300** stops.

If a relative code size satisfies a minimal code size threshold, a determination is optionally made whether the first atomic part of code is called by an additional microservice, block **332**. The system can determine whether loosely connected parts of a microservice are called by another microservice. For example, and without limitation, this can include the refactoring recommendation tool **134** determining whether the atomic part M of code **250** is called by an additional microservice. If the first atomic part of code is called by an additional microservice, the method **300** continues to block **334** to recommend moving the corresponding atomic part of code. If the first atomic part of code is not called by an additional microservice, the method **300** stops.

If the first atomic part of code is called by an additional microservice, a recommendation is optionally output to move the first atomic part of code to the additional microservice, block **334**. The system can recommend moving loosely connected parts of a microservice to a calling microservice. For example, and without limitation, this can include the refactoring recommendation tool **134** outputting a recommendation to move the atomic part M of code **250** to the web Backend for Frontend **216**, which calls the atomic part M of code **250**.

Although FIG. **3** depicts the blocks **302-334** occurring in a specific order, the blocks **302-334** may occur in another order. In other implementations, each of the blocks **302-334** may also be executed in combination with other blocks and/or some blocks may be divided into a different set of blocks.

Having described the subject matter in detail, an exemplary hardware device in which the subject matter may be implemented shall be described. Those of ordinary skill in the art will appreciate that the elements illustrated in FIG. **4** may vary depending on the system implementation. With reference to FIG. **4**, an exemplary system for implementing the subject matter disclosed herein includes a hardware device **400**, including a processing unit **402**, memory **404**, storage **406**, data entry module **408**, display adapter **410**, communication interface **412**, and a bus **414** that couples elements **404-412** to the processing unit **402**.

The bus **414** may comprise any type of bus architecture. Examples include a memory bus, a peripheral bus, a local bus, etc. The processing unit **402** is an instruction execution machine, apparatus, or device and may comprise a microprocessor, a digital signal processor, a graphics processing unit, an application specific integrated circuit (ASIC), a field programmable gate array (FPGA), etc. The processing unit **402** may be configured to execute program instructions stored in memory **404** and/or storage **406** and/or received via data entry module **408**.

The memory **404** may include read only memory (ROM) **416** and random access memory (RAM) **418**. Memory **404** may be configured to store program instructions and data during operation of device **400**. In various embodiments, memory **404** may include any of a variety of memory technologies such as static random access memory (SRAM) or dynamic RAM (DRAM), including variants such as dual data rate synchronous DRAM (DDR SDRAM), error correcting code synchronous DRAM (ECC SDRAM), or RAMBUS DRAM (RDRAM), for example. Memory **404** may also include nonvolatile memory technologies such as nonvolatile flash RAM (NVRAM) or ROM. In some embodiments, it is contemplated that memory **404** may include a combination of technologies such as the foregoing, as well as other technologies not specifically mentioned. When the subject matter is implemented in a computer system, a basic input/output system (BIOS) **420**, containing the basic routines that help to transfer information between elements within the computer system, such as during start-up, is stored in ROM **416**.

The storage **406** may include a flash memory data storage device for reading from and writing to flash memory, a hard disk drive for reading from and writing to a hard disk, a magnetic disk drive for reading from or writing to a removable magnetic disk, and/or an optical disk drive for reading from or writing to a removable optical disk such as a CD ROM, DVD or other optical media. The drives and their associated computer-readable media provide nonvolatile storage of computer readable instructions, data structures, program modules and other data for the hardware device **400**.

It is noted that the methods described herein may be embodied in executable instructions stored in a computer readable medium for use by or in connection with an instruction execution machine, apparatus, or device, such as a computer-based or processor-containing machine, apparatus, or device. It will be appreciated by those skilled in the art that for some embodiments, other types of computer readable media may be used which can store data that is accessible by a computer, such as magnetic cassettes, flash memory cards, digital video disks, Bernoulli cartridges, RAM, ROM, and the like may also be used in the exemplary operating environment. As used here, a "computer-readable medium" can include one or more of any suitable media for storing the executable instructions of a computer program in one or more of an electronic, magnetic, optical, and electromagnetic format, such that the instruction execution machine, system, apparatus, or device can read (or fetch) the instructions from the computer readable medium and execute the instructions for carrying out the described methods. A non-exhaustive list of conventional exemplary computer readable medium includes: a portable computer diskette; a RAM; a ROM; an erasable programmable read only memory (EPROM or flash memory); optical storage devices, including a portable compact disc (CD), a portable digital video disc (DVD), a high definition DVD (HD-DVD™), a BLU-RAY disc; and the like.

A number of program modules may be stored on the storage **406**, ROM **416** or RAM **418**, including an operating system **422**, one or more applications programs **424**, program data **426**, and other program modules **428**. A user may enter commands and information into the hardware device **400** through data entry module **408**. Data entry module **408** may include mechanisms such as a keyboard, a touch screen, a pointing device, etc. Other external input devices (not shown) are connected to the hardware device **400** via external data entry interface **430**. By way of example and not limitation, external input devices may include a microphone, joystick, game pad, satellite dish, scanner, or the like. In some embodiments, external input devices may include video or audio input devices such as a video camera, a still camera, etc. Data entry module **408** may be configured to receive input from one or more users of device **400** and to deliver such input to processing unit **402** and/or memory **404** via bus **414**.

A display **432** is also connected to the bus **414** via display adapter **410**. Display **432** may be configured to display output of device **400** to one or more users. In some embodiments, a given device such as a touch screen, for example, may function as both data entry module **408** and display **432**. External display devices may also be connected to the bus **414** via external display interface **434**. Other peripheral output devices, not shown, such as speakers and printers, may be connected to the hardware device **400**.

The hardware device **400** may operate in a networked environment using logical connections to one or more remote nodes (not shown) via communication interface **412**. The remote node may be another computer, a server, a router, a peer device or other common network node, and typically includes many or all of the elements described above relative to the hardware device **400**. The communication interface **412** may interface with a wireless network and/or a wired network. Examples of wireless networks include, for example, a BLUETOOTH network, a wireless personal area network, a wireless 802.11 local area network (LAN), and/or wireless telephony network (e.g., a cellular, PCS, or GSM network). Examples of wired networks include, for example, a LAN, a fiber optic network, a wired personal area network, a telephony network, and/or a wide area network (WAN). Such networking environments are commonplace in intranets, the Internet, offices, enterprise-wide computer networks and the like. In some embodiments, communication interface **412** may include logic configured to support direct memory access (DMA) transfers between memory **404** and other devices.

In a networked environment, program modules depicted relative to the hardware device **400**, or portions thereof, may be stored in a remote storage device, such as, for example, on a server. It will be appreciated that other hardware and/or software to establish a communications link between the hardware device **400** and other devices may be used.

It should be understood that the arrangement of hardware device **400** illustrated in FIG. **4** is but one possible implementation and that other arrangements are possible. It should also be understood that the various system components (and means) defined by the claims, described below, and illustrated in the various block diagrams represent logical components that are configured to perform the functionality described herein. For example, one or more of these system components (and means) may be realized, in whole or in part, by at least some of the components illustrated in the arrangement of hardware device **400**.

In addition, while at least one of these components are implemented at least partially as an electronic hardware component, and therefore constitutes a machine, the other components may be implemented in software, hardware, or a combination of software and hardware. More particularly, at least one component defined by the claims is implemented at least partially as an electronic hardware component, such as an instruction execution machine (e.g., a processor-based or processor-containing machine) and/or as specialized circuits or circuitry (e.g., discrete logic gates interconnected to perform a specialized function), such as those illustrated in FIG. **4**.

Other components may be implemented in software, hardware, or a combination of software and hardware. Moreover, some or all of these other components may be combined, some may be omitted altogether, and additional components may be added while still achieving the functionality described herein. Thus, the subject matter described herein may be embodied in many different variations, and all such variations are contemplated to be within the scope of what is claimed.

In the preceding description, the subject matter was described with reference to acts and symbolic representations of operations that are performed by one or more devices, unless indicated otherwise. As such, it will be understood that such acts and operations, which are at times referred to as being computer-executed, include the manipulation by the processing unit of data in a structured form. This manipulation transforms the data or maintains it at locations in the memory system of the computer, which reconfigures or otherwise alters the operation of the device in a manner well understood by those skilled in the art. The data structures where data is maintained are physical locations of the memory that have particular properties defined by the format of the data. However, while the subject matter is being described in the preceding context, it is not meant to be limiting as those of skill in the art will appreciate that various of the acts and operations described hereinafter may also be implemented in hardware.

To facilitate an understanding of the subject matter described herein, many aspects are described in terms of sequences of actions. At least one of these aspects defined by the claims is performed by an electronic hardware component. For example, it will be recognized that the various actions may be performed by specialized circuits or circuitry, by program instructions being executed by one or more processors, or by a combination of both. The description herein of any sequence of actions is not intended to imply that the specific order described for performing that sequence must be followed. All methods described herein may be performed in any suitable order unless otherwise indicated herein or otherwise clearly contradicted by context.

While one or more implementations have been described by way of example and in terms of the specific embodiments, it is to be understood that one or more implementations are not limited to the disclosed embodiments. To the contrary, it is intended to cover various modifications and similar arrangements as would be apparent to those skilled in the art. Therefore, the scope of the appended claims should be accorded the broadest interpretation so as to encompass all such modifications and similar arrangements.

What is claimed is:

1. A system comprising:

one or more processors; and

a non-transitory computer readable medium storing a plurality of instructions, which when executed, cause the one or more processors to:

generate a graph of connected nodes comprising a first node, which represents a first atomic part of code in a microservice in an application, and a second node, which represents a second atomic part of code in the microservice;

determine a nodes connection score based on any connections between the first node and the second node;

determine whether the nodes connection score satisfies a nodes connection threshold;

determine a relative code size based on comparing a size associated with the first atomic part of code against a size of the microservice, in response to a determination that the nodes connection score does not satisfy the nodes connection threshold;

determine whether the relative code size satisfies a code size threshold; and output a recommendation to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice, in response to a determination that the relative code size satisfies the code size threshold.

2. The system of claim **1**, wherein the plurality of instructions further causes the processor to

determine whether the relative code size satisfies a minimal code size threshold, in response to a determination that the relative code size does not satisfy the code size threshold;

determine whether the first atomic part of code is called by an additional microservice, in response to a determination that the relative code size does not satisfy the minimal code size threshold; and

output a recommendation to move the first atomic part of code to the additional microservice, in response to a determination that the first atomic part of code is called by the additional microservice.

3. The system of claim **1**, wherein the plurality of instructions further causes the processor to:

determine a segments similarity score based on comparing first code segments, associated with a first microservice in the application, against second code segments, associated with a second microservice in the application;

determine whether the segments similarity score satisfies a segments similarity threshold;

determine microservices similarity scores based on comparing a size of similar code segments in the first code segments and the second code segments against sizes of the first microservice and the second microservice, in response to a determination that the segments similarity score satisfies the segments similarity threshold:

determine whether any microservices similarity score satisfies a microservices similarity threshold; and

output a recommendation to merge the first microservice with the second microservice, in response to a determination that any microservices similarity score satisfies the microservices similarity threshold.

4. The system of claim **3**, wherein the plurality of instructions further causes the processor to determine whether the size of similar code segments satisfies a segments size threshold, in response to a determination that not any microservices similarity scores satisfy the microservices similarity threshold.

5. The system of claim **4**, wherein the plurality of instructions further causes the processor to output a recommendation to move the similar code segments from the second microservice to the first microservice, in response to a determination that the size of similar code segments satisfies the segments size threshold.

6. The system of claim **5**, wherein moving the similar code segments from the second microservice to the first microservice comprises linking the second microservice to the similar code segments in the first microservice and deleting the similar code segments from the second microservice.

7. The system of claim **4**, wherein the plurality of instructions further causes the processor to output a recommendation to create a third microservice and to move the similar code segments in the first code segments and the second code segments to the third microservice, in response to a determination that the size of the similar code segments satisfies the segments size threshold.

8. A method comprising:

generating a graph of connected nodes comprising a first node, which represents a first atomic part of code in a microservice in an application, and a second node, which represents a second atomic part of code in the microservice;

determining a nodes connection score based on any connections between the first node and the second node;

determining whether the nodes connection score satisfies a nodes connection threshold;

determining a relative code size based on comparing a size associated with the first atomic part of code against a size of the microservice, in response to a determination that the nodes connection score does not satisfy the nodes connection threshold;

determining whether the relative code size satisfies a code size threshold; and

outputting a recommendation to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice, in response to a determination that the relative code size satisfies the code size threshold.

9. The method of claim **8**, wherein the computer-implemented method further comprises:

determining whether the relative code size satisfies a minimal code size threshold, in response to a determination that the relative code size does not satisfy the code size threshold;

determining whether the first atomic part of code is called by an additional microservice, in response to a determination that the relative code size does not satisfy the minimal code size threshold; and

outputting a recommendation to move the first atomic part of code to the additional microservice, in response to a determination that the first atomic part of code is called by the additional microservice.

10. The method of claim **8**, wherein the computer-implemented method further comprises:

determining a segments similarity score based on comparing first code segments, associated with a first microservice in the application, against second code segments, associated with a second microservice in the application;

determining whether the segments similarity score satisfies a segments similarity threshold;

determining microservices similarity scores based on comparing a size of similar code segments in the first code segments and the second code segments against sizes of the first microservice and the second microservice, in response to a determination that the segments similarity score satisfies the segments similarity threshold:

determining whether any microservices similarity score satisfies a microservices similarity threshold; and

outputting a recommendation to merge the first microservice with the second microservice, in response to a determination that any microservices similarity score satisfies the microservices similarity threshold.

11. The method of claim **10**, wherein the computer-implemented method further comprises determining whether the size of similar code segments satisfies a segments size threshold, in response to a determination that not any microservices similarity scores satisfy the microservices similarity threshold.

12. The method of claim 11, wherein the computer-implemented method further comprises outputting a recommendation to move the similar code segments from the second microservice to the first microservice, in response to a determination that the size of similar code segments satisfies the segments size threshold.

13. The method of claim 12, wherein moving the similar code segments from the second microservice to the first microservice comprises linking the second microservice to the similar code segments in the first microservice and deleting the similar code segments from the second microservice.

14. The method of claim 11, wherein the computer-implemented method further comprises outputting a recommendation to create a third microservice and to move the similar code segments in the first code segments and the second code segments to the third microservice, in response to a determination that the size of the similar code segments satisfies the segments size threshold.

15. A computer program product, comprising a non-transitory computer-readable medium having a computer-readable program code embodied therein to be executed by one or more processors, the program code including instructions to:

generate a graph of connected nodes comprising a first node, which represents a first atomic part of code in a microservice in an application, and a second node, which represents a second atomic part of code in the microservice;

determine a nodes connection score based on any connections between the first node and the second node;

determine whether the nodes connection score satisfies a nodes connection threshold;

determine a relative code size based on comparing a size associated with the first atomic part of code against a size of the microservice, in response to a determination that the nodes connection score does not satisfy the nodes connection threshold;

determine whether the relative code size satisfies a code size threshold; and

output a recommendation to disconnect the first atomic part of code from the microservice, create another microservice in the application, and connect the first atomic part of code to the other microservice, in response to a determination that the relative code size satisfies the code size threshold.

16. The computer program product of claim 15, wherein the program code includes further instructions to:

determine whether the relative code size satisfies a minimal code size threshold, in response to a determination that the relative code size does not satisfy the code size threshold;

determine whether the first atomic part of code is called by an additional microservice, in response to a determination that the relative code size does not satisfy the minimal code size threshold; and

output a recommendation to move the first atomic part of code to the additional microservice, in response to a determination that the first atomic part of code is called by the additional microservice.

17. The computer program product of claim 15, wherein the program code includes further instructions to:

determine a segments similarity score based on comparing first code segments, associated with a first microservice in the application, against second code segments, associated with a second microservice in the application;

determine whether the segments similarity score satisfies a segments similarity threshold;

determine microservices similarity scores based on comparing a size of similar code segments in the first code segments and the second code segments against sizes of the first microservice and the second microservice, in response to a determination that the segments similarity score satisfies the segments similarity threshold:

determine whether any microservices similarity score satisfies a microservices similarity threshold; and

output a recommendation to merge the first microservice with the second microservice, in response to a determination that any microservices similarity score satisfies the microservices similarity threshold.

18. The computer program product of claim 17, wherein the program code includes further instructions to determine whether the size of similar code segments satisfies a segments size threshold, in response to a determination that not any microservices similarity scores satisfy the microservices similarity threshold.

19. The computer program product of claim 18, wherein the program code includes further instructions to output a recommendation to move the similar code segments from the second microservice to the first microservice, wherein moving the similar code segments from the second microservice to the first microservice comprises linking the second microservice to the similar code segments in the first microservice and deleting the similar code segments from the second microservice, in response to a determination that the size of similar code segments satisfies the segments size threshold.

20. The computer program product of claim 18, wherein the program code includes further instructions to output a recommendation to create a third microservice and to move the similar code segments in the first code segments and the second code segments to the third microservice, in response to a determination that the size of the similar code segments satisfies the segments size threshold.

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